भारतीय मानक **IS 11315 (Part 5) : 2023**

Indian Standard

रॉक मास में दरारों के मात्रात्मक विवरण के तरीके

भाग 5 दीवार की मज़बूती

(पहला पुनरीक्षण)

Methods for Quantitative Description of Discontinuities in Rock Masses

Part 5 Wall Strength

(First Revision)

ICS 93.060

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Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard (Part 5) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

A series of Indian Standard on test methods for assessing the strength characteristics of rocks and rock masses are being developed/revised in view of recent advances in the field of rock mechanics. The majority of rock masses, in particular, those within a few hundred metres from the surface, behave as discontinuous, with the discontinuities largely determining the mechanical behaviour. It is, therefore, essential that structure of a rock mass and the nature of its discontinuities are carefully described and quantified to have a complete and unified descriptions of rock masses and discontinuities. Careful field descriptions will enhance the value of in-situ tests that are performed since the interpretation and extrapolation of results will be made more reliable.

Discontinuity is the general term for any mechanical discontinuity in a rock mass, along which the rock mass has zero or low tensile strength. It is the collective term for most types of joints, weak bedding planes, weak schistosity planes, weakness zones, shear zones and faults. The ten parameters selected for rock mass survey to describe discontinuities are orientation, spacing, persistence, roughness, wall strength, aperture, filling, seepage, number of sets and block size. These parameters are also evaluated from the study of drill cores to obtain information on the discontinuities.

It is essential that both the structures of a rock mass and the nature of its discontinuities are carefully described for determining the mechanical behaviour. This Indian Standard, covering various parameters to describe discontinuities in rock masses.

This standard (Part 5) covers the methods for quantitative description of discontinuities in rock masses for wall strength. This standard (Part 5) was first formulated in 1987. This revision incorporates the latest advancement and modifications based on the experience gained in the use of this standard. The other parts formulated in the series are:

Part 1	Orientation
Part 2	Spacing
Part 3	Persistence
Part 4	Roughness
Part 6	Aperture
Part 7	Filling
Part 8	Seepage
Part 9	Number of sets
Part 10	Block size
Part 11	Core recovery and rock quality designation
Part 12	Drill core study

Wall strength describes the equivalent wall strength of the adjacent rock walls of a discontinuity. Wall strength may be lower than rock block strength due to weathering or alteration of the walls. Wall strength is an important component of shear strength in contact. If rock walls are in contact.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASSES

PART 5 WALL STRENGTH

(First Revision)

1 SCOPE

This standard (Part 5) covers the method for evaluation and description of the compressive strength of the rock comprising the walls of a discontinuity in rock mass.

2 REFERENCES

The standards given below contains provisions, which through reference in this text, constitutes provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards:

IS No.	*Title*
IS 11315 (Part 4) : 1987	Method for the quantitative description of discontinuities in rock mass: Part 4 Roughness
IS 11358 : 1987	Glossary of terms and symbols relating to rock mechanics
IS 12608 : 1989	Method for determination of hardness of rock

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 11358 shall apply.

4 GENERAL

4.1 The compressive strength of the rock comprising the walls of a discontinuity is a very important component of shear strength and deformability, especially if the walls are in direct rock to rock contact as in the case of unfilled joints. Slight shear displacement of individual joints caused by shear stresses within the rock mass often results in very small asperity contact areas and actual stresses locally approaching or exceeding the compressive strength of the rock wall material, hence the asperity damage.

4.2 Rock masses are frequently weathered near the surface, and are sometimes altered by hydrothermal processes. The weathering (and alteration) generally affects the walls of discontinuities more than the interior of rock blocks. This result in a reduction of wall strength by some fraction of what would be measured on the fresher rock found in the interior of the rock blocks, for example, that sampled by drill core. A description of the state of weathering or alteration, both for the rock material and for the rock mass is, therefore, an essential part of the description of wall strength.

4.3 There are two main results of weathering – one dominated by mechanical disintegration, the other by chemical decomposition including solution. Generally, both mechanical and chemical effects act together, but depending on climatic regime, one or other of these aspects may be dominant. Mechanical weathering results in opening of discontinuities, the formation of new discontinuities by rock fracture, the opening of grain boundaries, and the fracture or cleavage of individual mineral grains. Chemical weathering results in discolouration of the rock and leads to the eventual decomposition of silicate minerals to clay minerals; some minerals, notably quartz resist this action and may survive unchanged. Solution is an aspect of chemical weathering and is particularly important in the case of carbonate and saline minerals.

4.4 The relatively thin 'skin' of wall rock affects shear strength and deformability can be tested by means of simple index tests. The apparent uniaxial compressive strength can be estimated both from Schmidt hammer tests and from scratch and geological hammer tests, since the latter have been roughly calibrated against large body of test data. The detail of Schmidt hammer is given in IS 12608.

4.5 Mineral coatings will affect the shear strength of discontinuities to a marked degree if the walls are planar and smooth. The type of mineral coatings should be described, where possible. Samples should be taken when in doubt.

4.6 Strength of rock walls of a continuity in rock mass is governed by the state of weathering (and alteration) of the rock mass Table 1 and rock material Table 2. Quantitative estimates of strength of rock can be made by manual index tests Table 3 and Schmidt hammer tests (Fig. 1).

4.6.1 Schmidt hammer test is recommended for obtaining estimates of wall strength for subsequent calculation of shear strength when utilizing the wall roughness coefficient as described in Part 4.

4.7 Equipment required for evaluation of wall strength in rock mass survey consist of geological hammer with one tapered point, strong pen knife or similar sharp tool, Schmidt hammer (L type) with conversion table (table generally supplied by the manufacturer) to correct for orientation and graph (*see* Fig. 1) to convert corrected rebound number to an estimate of uniaxial strength, and equipment for measuring dry density of small rock samples, for example, oven, balance, pycnometer, beaker, etc.

Table 1 State of Weathering of Rock Mass

(*Clauses* 4.6 *and* 5.1)

Sl No.	Term	Description	Grade
(1)	(2)	(3)	(4)
i)	Fresh	No visible sign of rock material weathering: perhaps slight discolouration on major discontinuity surfaces	I
ii)	Slightly weathered	Discolouration indicates weathering of rock material. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition	II
iii)	Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discoloured rock is present either as a continuous framework or as core stones	III
iv)	Highly weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discoloured rock is present either as a discontinuous framework or as core stones	IV
v)	Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
vi)	Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported	VI

Table 2 State of Weathering of Rock Material

(*Clauses* 4.6 *and* 5.2)

Sl No.	Term	Description
(1)	(2)	(3)
i)	Fresh	No visible sign of weathering of the rock material
	Discoloured	The colour of the original fresh rock material is changed. The degree of change from the original colour should be indicated. If the colour change is confined to particular mineral constituents this should be mentioned
ii)	Decomposed	The rock is weathered to the condition of a soil in which the original material fabric is still intact, but some or all of the mineral grains are decomposed
iii)	Disintegrated	The rock is weathered to the condition of a soil in which the, original fabric is still intact. The rock is friable, but the mineral grains are not decomposed

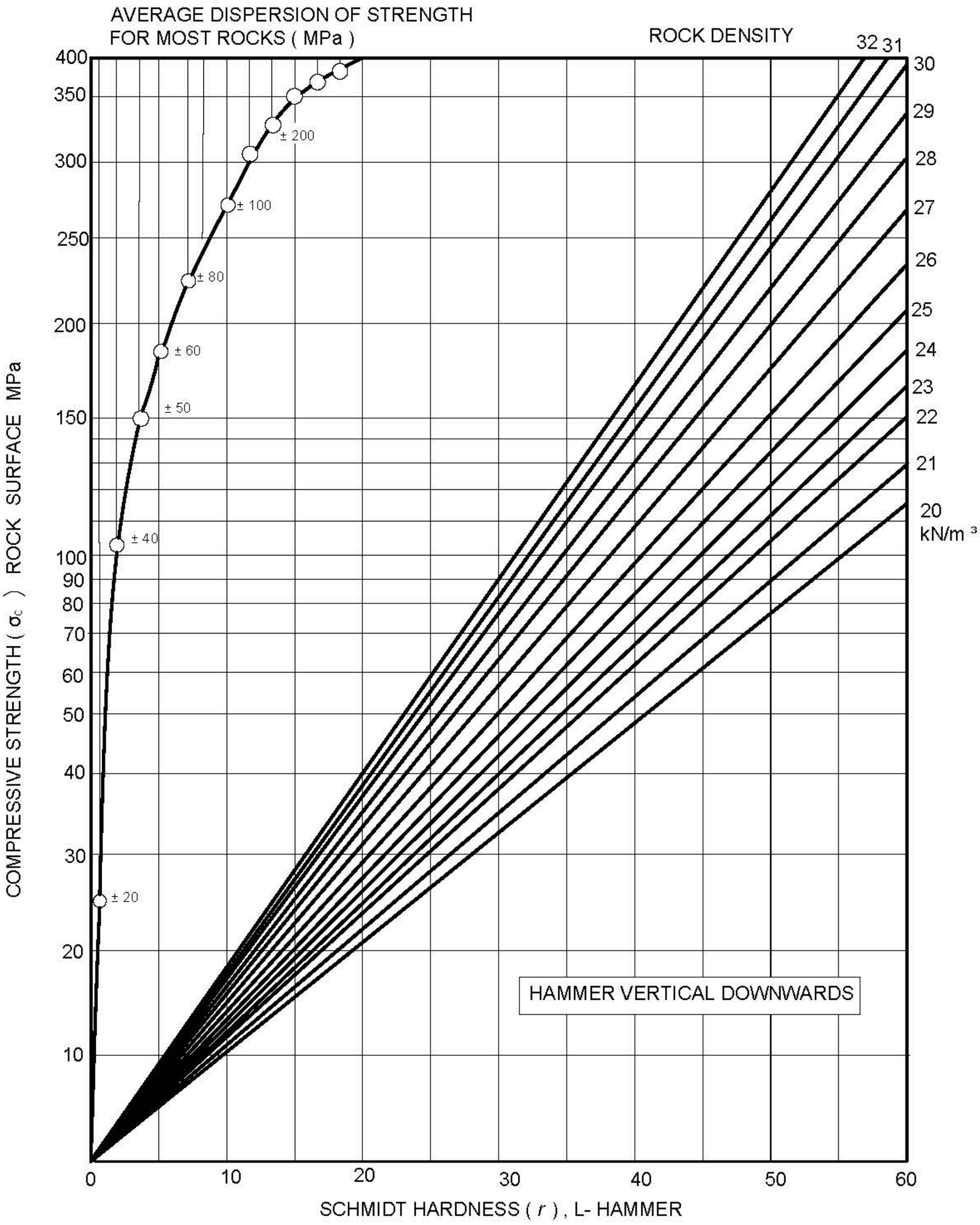
NOTE — The stages of weathering described above may be subdivided using qualifying terms, for example, 'slightly discoloured, 'moderately discoloured', 'highly discoloured', etc.

Table 3 Strength of Rock by Manual Index

(*Clauses* 4.6 a*nd* 5.3)

Grade	Description	Field Identification	Approximate Range of Uniaxial Compressive Strength (MPa)
(1)	(2)	(3)	(4)
S1	Very soft clay	Easily penetrated several inches by fist	< 0.025
S2	Soft day	Easily penetrated several inches by thumb	0.025-0.05
S3	Firm clay	Can be penetrated several inches by thumb with moderate effort	0.05-0.10
S4	Stiff clay	Readily indented by thumb but penetrated only with great effort	0.10-0.25
S5	Very stiff clay	Readily indented by thumb-nail	0.25-0.50
S6	Hard clay	Indented with difficulty by thumb-nail	> 0.50
R0	Extremely weak rock	Indented by thumb-nail	0.25-1.0
R1	Very weak rock	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0-5.0
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0-25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25-50
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it	50-100
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it	100-250
R6	Extremely strong rock	Specimen can only be chipped with geological hammer	> 250

NOTE — Grades S1 to S6 apply to cohesive soils, for example, clays, silty clays, and combinations of silts and clays with sand, generally slow draining. Discontinuity wall strength will generally be characterized by grade R0 to R6 (rock) while S1 to S6 (clay) will generally apply to filled discontinuities.



SCHMIDT HARDNESS (r), L-HAMMER

FIG. 1 CORRELATION CHART FOR SCHMIDT (L) HAMMER RELATING ROCK DENSITY, COMPRESSIVE STRENGTH AND REBOUND NUMBER

5 PROCEDURE

5.1 The grade of weathering (or alteration) of the rock mass as a whole is described first. Table 1 gives the general terms and descriptions and may be modified to suit particular situations.

5.2 The grade of weathering (or alteration) of the rock material comprising of the walls of individual discontinuities or of the walls of a particular set of discontinuities (for example, an unfavorably orientated set of joints) should be described according to terms and descriptions shown in Table 2.

NOTES

1 Distribution of weathering grades in a rock mass may be determined by mapping natural and artificial exposures. However, it should be borne in mind that isolated natural exposures of rock and excavations of limited extent are not necessarily representative of the whole rock mass, since weathering can be extremely variable. The nature of any joint set at a location are to be observed at several possible places for alterations, filling, if any, before concluding about the value. The same joint set and even the same joint is likely to have different value in its different part. The most representative value to be reported.

2 Furthermore, all grades of weathering may not be seen in a given rock mass and in some cases a particular grade may be present to a very small extent. Distribution of various weathering grades of the rock material may be related to the porosity of the rock material and the presence of open discontinuities. In logging cores the distribution of weathering grades of the rock material may be recorded, but the distribution of weathering grades of the rock mass from which the cores were obtained can only be inferred.

3 Rock masses which are weathered due to exposure to or infiltration from surface agents should be distinguished where possible from those that are altered as a result of infiltration of hydrothermal solutions. However, in many instances the effects of alteration are not easily distinguished from those brought about by weathering.

4 An abundant class of rock materials, notably those with high clay content, are prone to swelling, weakening or disintegration when exposed to short term weathering processes of wetting and drying nature. Special tests are necessary to predict this aspect of mechanical performance.

5.3 The manual index tests detailed in Table 3 should be performed on the walls of discontinuities or on material representative of the walls. The choice and number of test locations will depend on the details required. The approximate range of strength for the walls of a critical set of joints may be sufficient. Alternatively, a single critical discontinuity may need to be characterized in details. The manual index tests can be performed on hand-sized pieces of freshly broken rock if the strength of intact rock bridges is of interest. Alternatively, the results of point load tests, if available, may be used to estimate the strength of the intact portions of any potential failure surface.

NOTES

1 The manual index tests are preferred to conventional tests on carefully prepared rock cylinders because a very large number of discontinuities can be sampled, thereby giving a more representative picture of the condition of the walls. Furthermore, conventional tests cannot be applied to the thin skin of wall rock or mineral coatings that dominate the shear strength and deformability of the rock mass.

2 The manual index tests for determining grades S1 to S6 can be replaced by more accurate assessment using a standard soil mechanics pocket penetrometer. This contains a stylus which is pressed into the sample at a constant rate. The maximum resistance can be read off a scale which is calibrated to show the maximum compressive strength of the sample. [This value is equal to twice the undrained shear strength = $\frac{1}{2}(\sigma_1 - \sigma_3)$]

5.4 The Schmidt hammer is applied in a direction perpendicular to the discontinuity wall of interest. The rock surface should be tested under saturated conditions to give the most conservative result. If the surfaces are unavoidably dry, this fact should be reported in the results. The surface should be free of loose particles, at least under the hammer position.

5.4.1 If the impulse from the spring-loaded projectile of the Schmidt hammer is sufficient to move the surface being tested, the resulting rebound will be artificially low. Such test results can normally be heard, since there is a 'drummy' sound. These results should be ignored. For the above reason this field index test is unsuitable in a loose rock mass containing very closely spaced discontinuities. (In such cases small block samples can be removed and tested when clamped rigidly to a heavy base).

5.4.2 Each surface of interest should be tested a number of times to ensure a representative set of results. It is suggested that tests are performed in groups of 10 (for example, 10 tests per discontinuity or 10 tests per unit area of a large critical discontinuity), applying the hammer to a new part of the surface before each impact. The five lowest readings of each group of 10 are discarded and the mean value, (r) of the five highest readings is quoted.

5.4.3 The mean values of the Schmidt rebound (r) and rock density (γ) for a given discontinuity are used to estimate the value of the joint wall compressive strength (JCS) using Fig. 1.

5.4.4 The Schmidt hammer test can be performed on the surfaces of or on material obtained from the freshly broken rock when the strength of the intact rock bridges (σ_c) is of interest. Alternatively, the results of point load tests, if available, can be used to estimate the strength of the intact portions of any potential failure surface.

5.4.5 Discontinuities with thin mineral coatings that appear quite persistent over a given surface and which would probably prevent initial rock to rock contact should be tested with the Schmidt hammer as above applying the hammer to the surface of the mineral coating. Depending upon the thickness of the mineral coating and its hardness, the estimate of JCS may or may not be relevant for estimation of shear strength. In all such cases of mineral coatings, the mineralogy should be described, for example, calcite, chlorite, talc, pyrite, graphite, kaolinite, etc samples should be taken when in doubt. An estimate of the area extent of the coating ± 10 percent and the range of the thickness of the coating (mm) should be included.

NOTES

1 The Schmidt hammer rebound number ranges in practice from about 10 to 60. The lowest number applies to 'weak' rocks (uniaxial compressive strength $\sigma_c < 20$ MPa), while the highest number applies to 'very strong' and 'extremely strong' rocks ($\sigma_c > 150$ MPa), 'very weak' rocks and 'extremely weak' rocks cannot be tested with the *L*-hammer. Manual index tests must therefore, be resorted to for rock weaker than 15 MPa to 20 MPa.

2 For a given strength of surface, the rebound number is minimum when the hammer is used vertically downwards (rebound against gravity) and maximum when used vertically upwards to vertical downwards tests only. The corrections given in the Table 4 should be applied when the hammer is used in other directions.

3 Block movement (drumminess) in closely jointed rock or crushing of loose grains are some of the reasons for unexpectedly low rebound numbers in a given set of results. Unexpectedly high readings are seldom obtained. The following two sets of actual results Illustrate the suggested method of obtaining a realistic mean value:

a) rough, planar iron-stained joints in granite
44, 36, 38, 44, 32, 44, 44, 40, 34, 42
(mean of highest 5 : r = 44)
(mean of 8 sets of 10 tests : r = 43); and

b) rough undulating calcite-coated joints in hornfels
28, 28, 30, 30, 28, 24, 24, 28, 30, 20
(mean of 3 sets of 10 tests : $r = 30$).

4 The Schmidt test is one of the few tests (with the exception of scratching tests) which takes into account the mechanical strength of the thin band of weathered wall material close to a discontinuity surface. Since it is this wall material which (in combination with roughness) controls the shear strength, it is of considerable importance as an index of rock quality. The joint wall compressive strength (JCS) is often as low as 25 percent of the adjacent intact rock strength (c) due to weathering effects.

6 PRESENTATION ON RESULTS

6.1 The weathering grades of recognizable weathering domains in the rock mass should be recorded on simplified sketches and/or vertical sections, with a clear key indicating the different weathering grades I, II, III, etc.

The weathering grade of the rock material of individual discontinuities or of specific discontinuity sets should be described, 'joint set No. 1: majority of walls moderately discoloured, approximately 20 percent fresh'.

6.2 The strength of the wall rock material of individual discontinuities or of specific discontinuity sets should be noted together with the assumed range of uniaxial compressive strength, 'joint set No. 1: majority medium strong (R3, 25 MPa to 50 MPa), approximately 20 percent strong (R4, 50 MPa to 100 MPa)'.

Values that are pertinent to the discontinuity walls should be carefully distinguished from any values that might have been recorded for the material representing the fresher rock within the rock blocks.

6.3 The mean rebound (r) for the wall rock material of individual discontinuities or of specific discontinuity sets should be noted together with the mean rock density (γ) and the estimate of wall strength (JCS) in MPa. One set of 10 results should be selected to show the typical range of rebound values.

Values that are pertinent to the discontinuity walls should be carefully distinguished from any values that might have been recorded for the material representing the fresher rock within the rock blocks.

Table 4 Corrections for Reducing Measured Schmidt Hammer Rebound (r) when the Hammer is not used Vertically Downwards

(*Clause* 5.4.5)

Sl No.	Rebound	Downwards		Upwards		Horizontal
	r	$x = -90$	$x = -45$	$x = +90$	$x = +45$	$x = 0$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	10	0	– 0.8	–	–	– 3.2
ii)	20	0	– 0.9	– 8.8	– 6.9	– 3.4
iii)	30	0	– 0.8	– 7.8	– 6.2	– 3.1
iv)	40	0	– 0.7	– 6.6	– 5.3	– 2.7
v)	50	0	– 0.6	– 5.3	– 4.3	– 2.2
vi)	60	0	– 0.4	– 4.0	– 3.3	– 1.7

ANNEX A
(*Foreword*)

COMMITTEE COMPOSITION

Rock Mechanics Sectional Committee, CED 48

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